



Mechanisms of drying-induced particle formation in mixtures of dairy proteins: a multiscale approach

L. Lanotte, C. Le Floch-Fouéré, F. Boissel, P. Schuck, R. Jeantet

Agrocampus Ouest, INRA, UMR 1253 Science and Technology of Milk and Eggs, F-35042 RENNES luca.lanotte@inra.fr

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A multidisciplinary and multiscale approach, reinforced by two high-calibre facilities:

Dairy Platform



Biological Resource Centre





Structuration / destructuration mechanisms of food matrix:

from structural characterisation to digestion



toward sustainable dairy systems

□ Microbial interaction:

food matrix and host cell





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Infant milk formula: the gold rush



IMF market : the key dairy industry challenge

- Globalization, economical transition and population growth
- From 2007, 8-20% annual growth → 2 million tons produced /year
- 80% of the European dairy investment since 2011
- China ~ 50% market → High added value

Mimicking breast milk

Microemulsion with multiple components

g/l	Cow milk	Human milk
Proteins	32	10
Caseins	80%	35%
WP	20%	65%
Carbohydrates	50	75
Lipids	38	36
PUFA	2,9%	6,4%

Adapted to the nutritional target

- First stage < 6 months
- Follow up < 36 months

Controlled functional end use properties





IMF functional properties = *f* (particle intrinsic properties) Insight on particle formation







Skin formation in drying droplets

ONSET OF INTERNAL FLOWS

Capillary flows to contrast liquid evaporation Marangoni flows induced by chemical and >thermal gradients



F. Giorgiutti-Dauphiné and L. Pauchard, Eur. Phys. J. E (2018) 41: 32.



Shell formation









Drying of dairy mixes

Materials

- Whey Protein Isolates (WPI)
- Native Phosphocaseinates (NPC)





micelle sponge-like

- Reference samples (WPI, NPC) \geq
 - Mixes o WPI/NPC 60/40 w (human milk, infant formula) o WPI/NPC 20/80 w (cow milk)

Concentration 120g*L⁻¹



HOW DOES MOLECULAR COMPOSITION IMPACT DROPLET SHAPE?



 \geq



Reference samples

Sadek et al., Langmuir, 2013, 29, 15606-15613. Sadek et al., Food Hydrocolloids, 2016, 52:161-166.





- II. Vacuole formation (WPI) Buckling (NPC)
 - (height)
- III. Evaporation completed



Mixes of dairy colloids

Single pendant droplet Scanning Electron Microscopy (SEM)



Flying monodisperse droplets Optical Microscopy



Evident morphological analogies despite different experimental conditions and particle size







Elemental analysis of the skin





Calcium

NPC

22,19 20,68

Small-on-top hypothesis

Film formation in binary colloidal mixtures





Zhou J. *et al.*, PRL 118, 108002 (2017). Fortini A. *et al.*, PRL 116, 118301 (2016). Accumulation of smaller components at the air-liquid interface

Osmotic pressure in proximity of the skin



Whey protein isolates on droplet external shell

L. Lanotte, F. Boissel, P. Schuck, R. Jeantet, C. Le Floch-Fouéré, *Drying-induced mechanisms of skin formation in mixtures of high protein dairy powders*, COLSUA (submitted).



Conclusions

Impact of sample composition on the evaporation of droplets of dairy protein
Role whey protein isolates (WPI) and phosphocaseinates (NPC) on skin development
Relation between mechanical properties at the molecular scale and macroscopic characteristics of dry particles

Perspectives

- Impact of overall solute concentration on the different stages of the drying process (optical visualization, mass measurements, SEM)
- Observation of the internal flows contributing to skin formation as a function of protein composition (confocal and optical microscopy)
- Evaluation of air-liquid interface mechanical properties throughout the evaporation process (acoustics)
- Development of a theoretical model for the drying of droplets of dairy mixtures (collaboration with L. Pauchard – FAST, Paris)





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